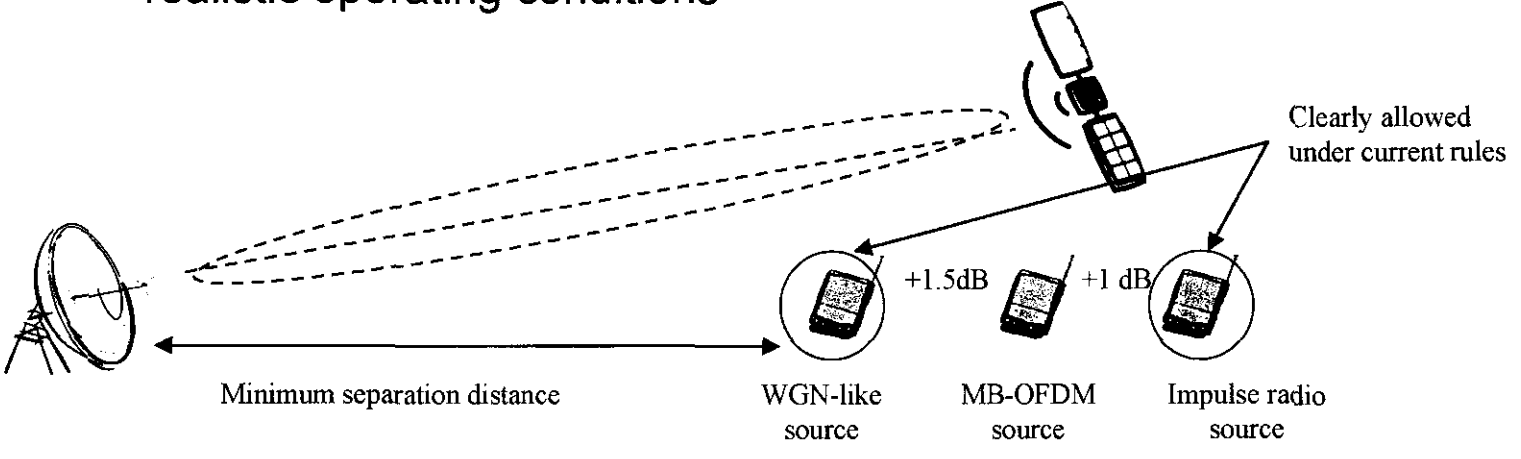
Executive Summary of Results

- Analysis, simulations, and measurements for wideband fixed satellite services (FSS) systems all come up with the same results
  - Interference from MB-OFDM waveforms is actually less than levels of interference caused by waveforms already allowed by the rules
  - Differences between all waveforms is on the order of 2-3 dB
- There is virtually no difference between DSSS, WGN, MB-OFDM, and impulse-UWB waveforms into narrowband receivers (less than 2.5 MHz)
- MB-OFDM waveforms can cause less interference than impulse radios in wideband receivers
  - MB-OFDM is ~ 1 dB better than 1 MHz PRF impulse radio
- WGN can cause less interference than MB-OFDM into wideband receivers
  - Difference between MB-OFDM and WGN interference is less than *1.5 dB* under realistic operating conditions



Substantial Interference Margin Exists with Current FCC Limits

- FCC/NTIA Interference results for various US government systems: Table taken directly from Final R&O and using the indoor mask

Most systems have substantial margin available

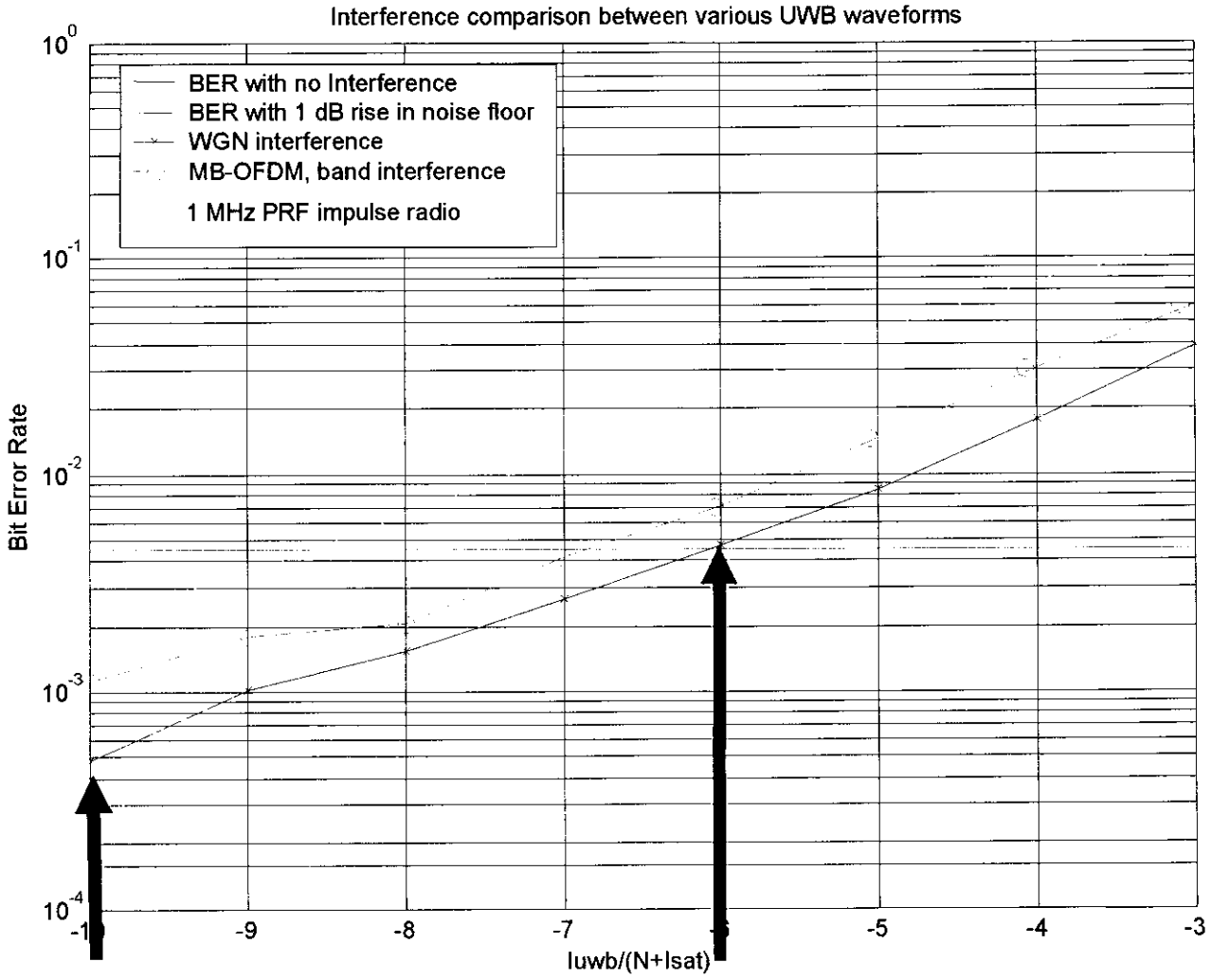
System	Frequency (MHz)	Maximum UWB EIRP (dBm/MHz) UWB Indoors 2 m height	Maximum UWB EIRP (dBm/MHz) UWB Indoors 30 m height	IF Bandwidth	Margin from current Part 15 limits
ARSR-4	1240-1370	-52	-73	690 KHz	23.3 dB (2 m) 2.3 dB (30 m)
SARSAT	1544-1545	-60	-57	800 KHz	15.3 dB (2 m) 18.3 dB (30 m)
ASR-9	2700-2900	-37	-57	653 KHz	14.3 dB (2 m)
NEXRAD	2700-2900	-33	-67	550 KHz	18.3 dB (2 m)
Marine Radar	2900-3100	-34	-45	4-20 MHz	17.3 dB (2 m) 6.3 dB (30 m)
FSS, 20 degrees	3700-4200	-24	-30	40 MHz	17.3 dB (2 m) 11.3 dB (30 m)
FSS*, 5 degrees	3700-4200	-39	-65	40 MHz	2.1 dB (2 m)
CW Altimeters	4200-4400	37	Not Applicable	N/A	78.3 dB (2 m)
Pulsed Altimeters	4200-4400	26	Not Applicable	30 MHz	67.3 dB (2 m)
MLS	5030-5091	-42	Not Applicable	150 KHz	-
TDWR	5600-5650	-23	-51	910 KHz	18.3 dB (2 m)

***: Most Direct TV/DSS/DTH receivers usually do not operate in 3.7-4.2 GHz C-band. They operate in 10.7-12.2 GHz Ku-band**

Simulation Results (Relative comparisons)

Fixed FSS performance results

- For a given performance, what is the increase in separation distance needed to maintain the same FSS performance?
  - 35 MHz symbol rate, 7/8 code rate, no interleaving, Es/(N+Isat)=7.6 dB (at sensitivity)



*Iuwb/(N+Isat) = -10 dB results in Iuwb/N = -6 dB which is a level defended by XSI in a contribution submitted to the FCC

0.5 dB rise in (N+Isat) *

1 dB rise in (N+Isat)

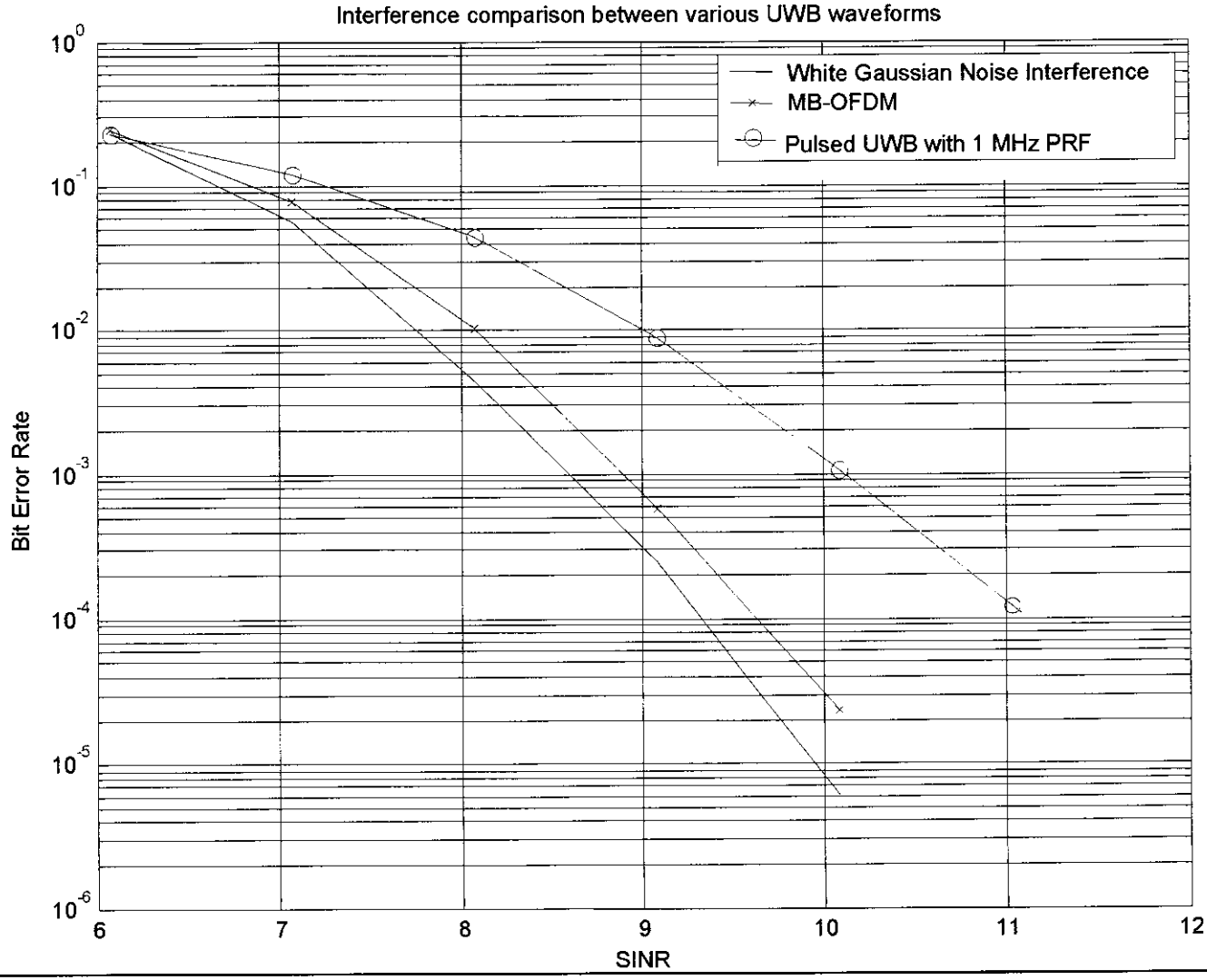
Fixed FSS performance results

- For a given performance, what is the increase in separation distance needed to maintain the same FSS performance?
  - Fixed FSS receiver performance (BER equivalent to 1 dB rise in SINR): 7/8 code

Interference Source	dB from WGN	Increase separation dist. (rel. to WGN, free space)	Increase separation dist. (rel. to WGN, path loss exp. = 3)
WGN	-	-	-
MB-OFDM	1 dB	12 %	8 %
1 MHz PRF Impulse	2.5 dB	33 %	21 %

Fixed UWB device separation distance

- For a given UWB device separation, what is the impact on FSS link margin?
  - 35 MHz, rate 7/8 coding, no interleaving, Iuwb/(N+Isat)=-4 dB



Fixed UWB device separation distance

- For a given UWB device separation, what is the impact on FSS link margin?
  - Fixed Separation distance (BER ¤ 10e-3) : 7/8 code (no interleaving)

Interference Source	Iuwb/(N+Isat)	Reduced FSS Margin (dB)	Difference from WGN (dB)
WGN	-10 dB	0.5 dB	-
	-6 dB	1 dB	-
	-4 dB	1.5 dB	-
MB-OFDM	-10 dB	0.5	0
	-6 dB	1.1	0.1
	-4 dB	1.75	0.25
1 MHz PRF pulse	-10 dB	0.75	0.25
	-6 dB	2	1
	-4 dB	3	1.5

Link Budget Analysis Showing Absolute Separation Distance Results and Impact of Assumptions

Absolute Separation Distance Results

- What is the absolute separation distance required between a UWB device (modeled here as WGN) and a FSS receiver?
  - What is the impact of assumptions used in the analysis?

Indoor parameters (includes 12 dB building attenuation factor)

Assumptions	Case 1 (Baseline)	Case 2	Case 3	Case 4	Case 5
		Changing 1 assumption at a time →			
Antenna Gain[1]	32-25log(θ)	**29-25log(θ)**	**29-25log(θ)**	**29-25log(θ)**	**29-25log(θ)**
Isat/N ratio[2]	-100 dB (no Isat)	-100 dB (no Isat)	**1.4 dB**	**1.4 dB**	**1.4 dB**
Path loss model	Free space (n=2)	Free space (n=2)	Free space (n=2)	**NLOS Path loss exp. (n=3)**	**NLOS Path loss exp. (n=3)**
Iuwb/(N+Isat) criteria	-10 dB	-10 dB	-10 dB	-10 dB	**-6 dB**

[1] Antenna gain in Case 1 proposed by SIA, gain in Case 2 proposed by XSI based on FCC 25.209 and ITU-R S.580.
[2] Isat/N = 1.4 dB derived from SIA filing to FCC, May 2003.

Absolute Separation Distance Results

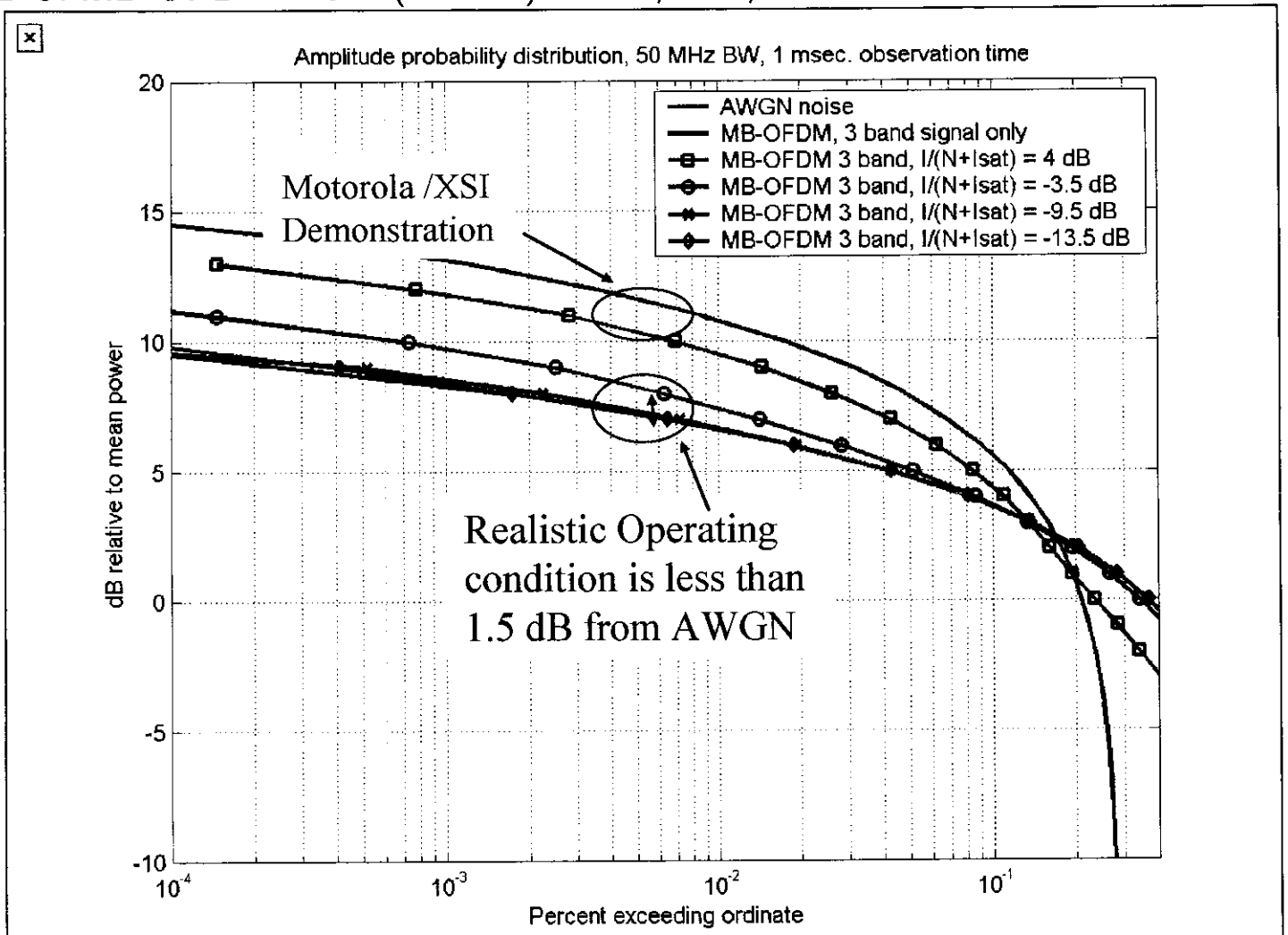
20 degree indoor					
FSS Interference Table	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**
Tx Power	-41.30	-41.30	-41.30	-41.30	-41.30
FSS Antenna angle (deg.)	20.00	20.00	20.00	20.00	20.00
Antenna Gain	-0.53	-3.53	-3.53	-3.53	-3.53
Center freq. (GHz)	3.75	3.75	3.75	3.75	3.75
Breakpoint (BP) (m)	1.00	1.00	1.00	1.00	1.00
Building attenuation (dB)	12	12	12	12	12
Rx power at BP (dBm)	-85.75	-88.75	-88.75	-88.75	-88.75
Noise floor (N) (dBm)	-117.00	-117.00	-117.00	-117.00	-117.00
Isat/N ratio (dB)	-100.00	-100.00	1.40	1.40	1.40
(N+Isat) floor (dBm)	-117	-117	-113.234	-113.234	-113.234
Iuwb/(N+Isat) criteria (dB)	-10	-10	-10	-10	-6
Max. Iuwb (dBm)	-127	-127	-123.234	-123.234	-119.234
Path loss required (dB)	29.25	26.25	22.49	22.49	18.49
Path loss exp. after BP	2	2	2	3	3
Min. separation dist (m)	29.013	20.53963	13.31279	5.617107	4.132182

~17 dB difference depending on system assumptions
(vs. 1-3 dB difference depending on structure of UWB waveform

Amplitude Probability Distribution (APD) Analysis

APD[1] for MB-OFDM with different I/(N+Isat)

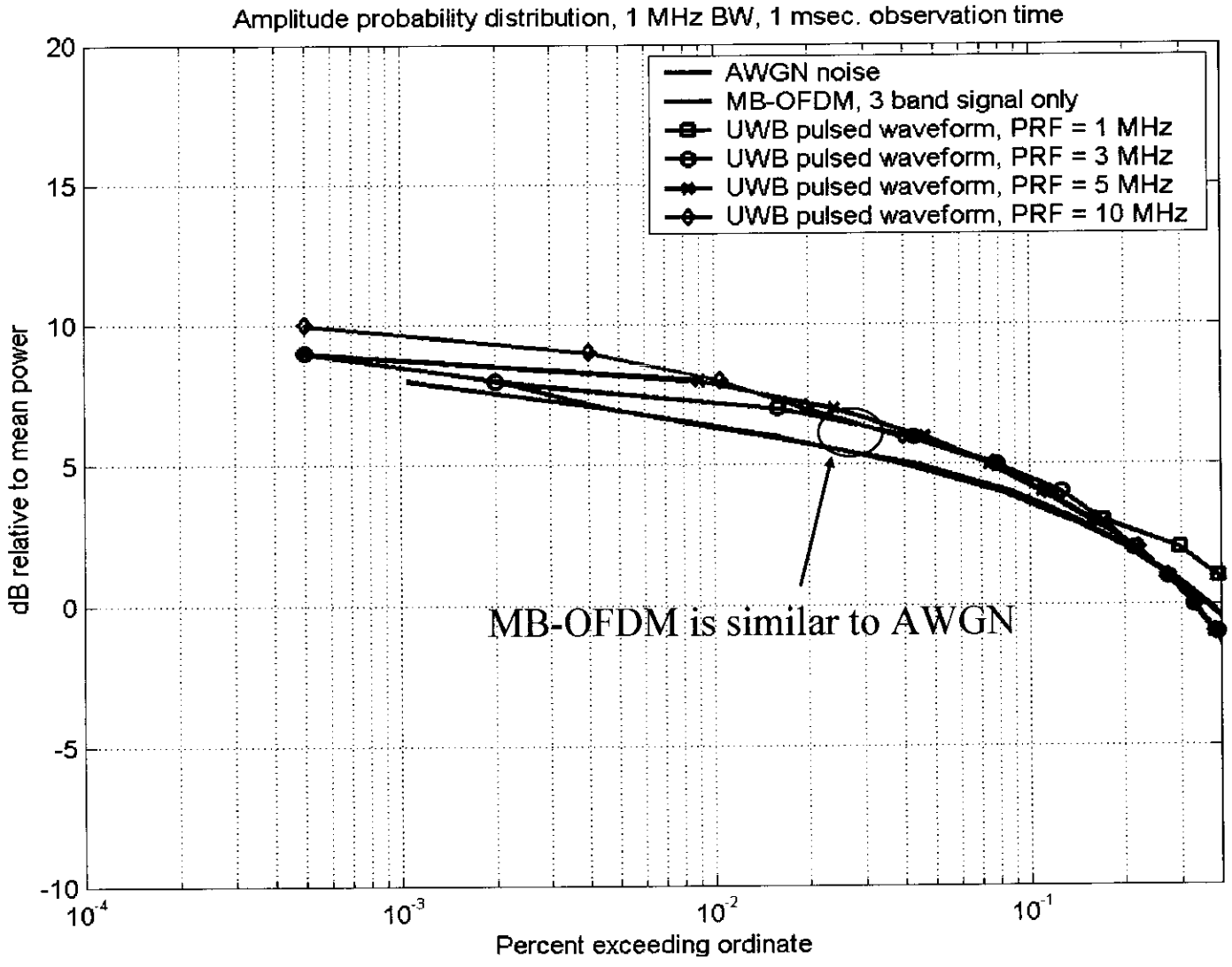
- The APD of MB-OFDM with I/(N+Isat) = -3.5, -9.5, -13.5 is less than 1.5 dB from AWGN.



[1] *Many modern digital receivers use elaborate error correction and time-interleaving techniques to correct errors in the received bit sequence. In such receivers, the corrected BER delived to the user will be substantially different from the received BER. Computation of BERs in these receivers will require much more detailed interference information than is contained in the APDs.* [R. Achatz, NTIA, Appendix A. Tutorial on Using Amplitude Probability Distributions to Characterize the Interference of Ultrawideband Transmitters to Narrowband Receivers]

APDs for narrowband receivers

- MB-OFDM APD is similar to AWGN with a 1 MHz resolution bandwidth.

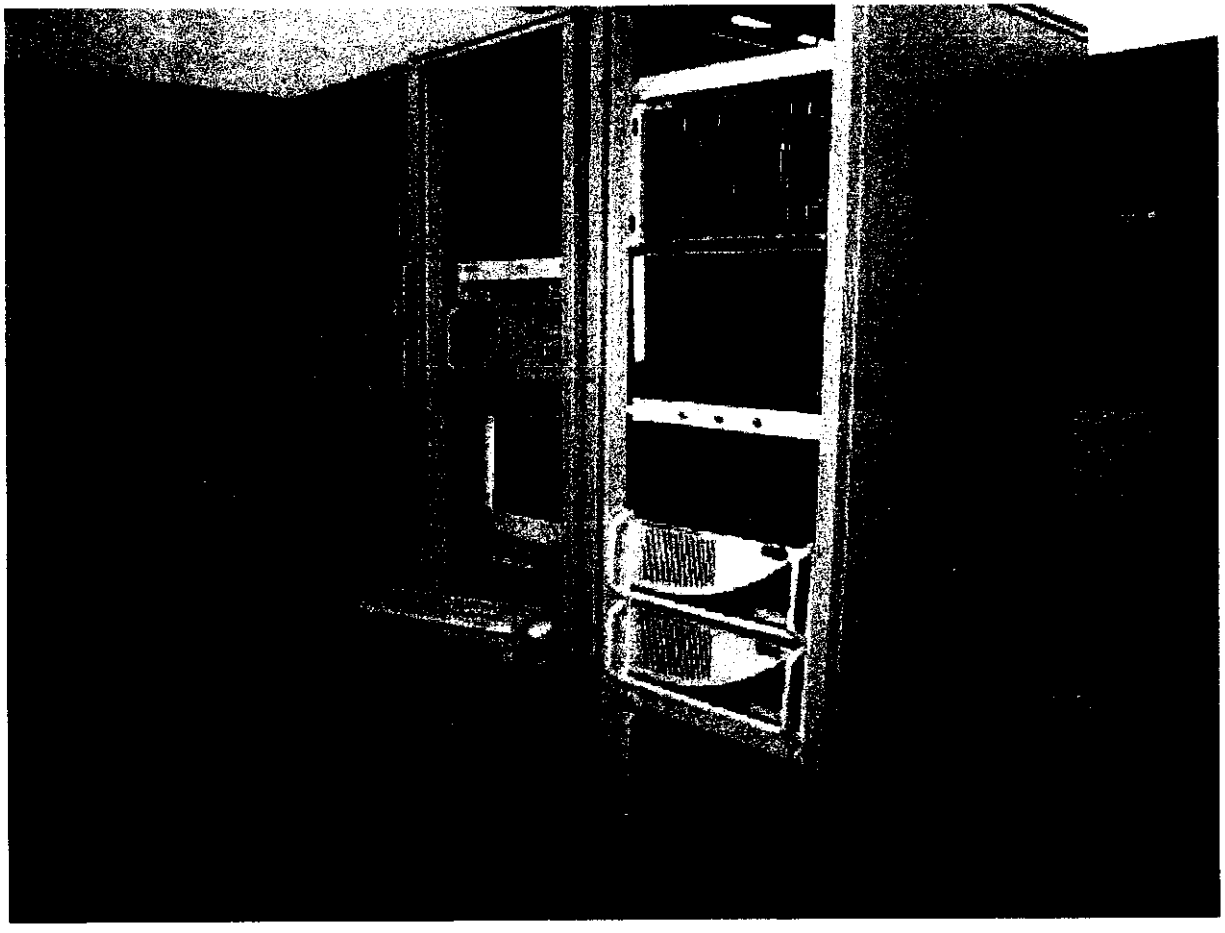


Measurements

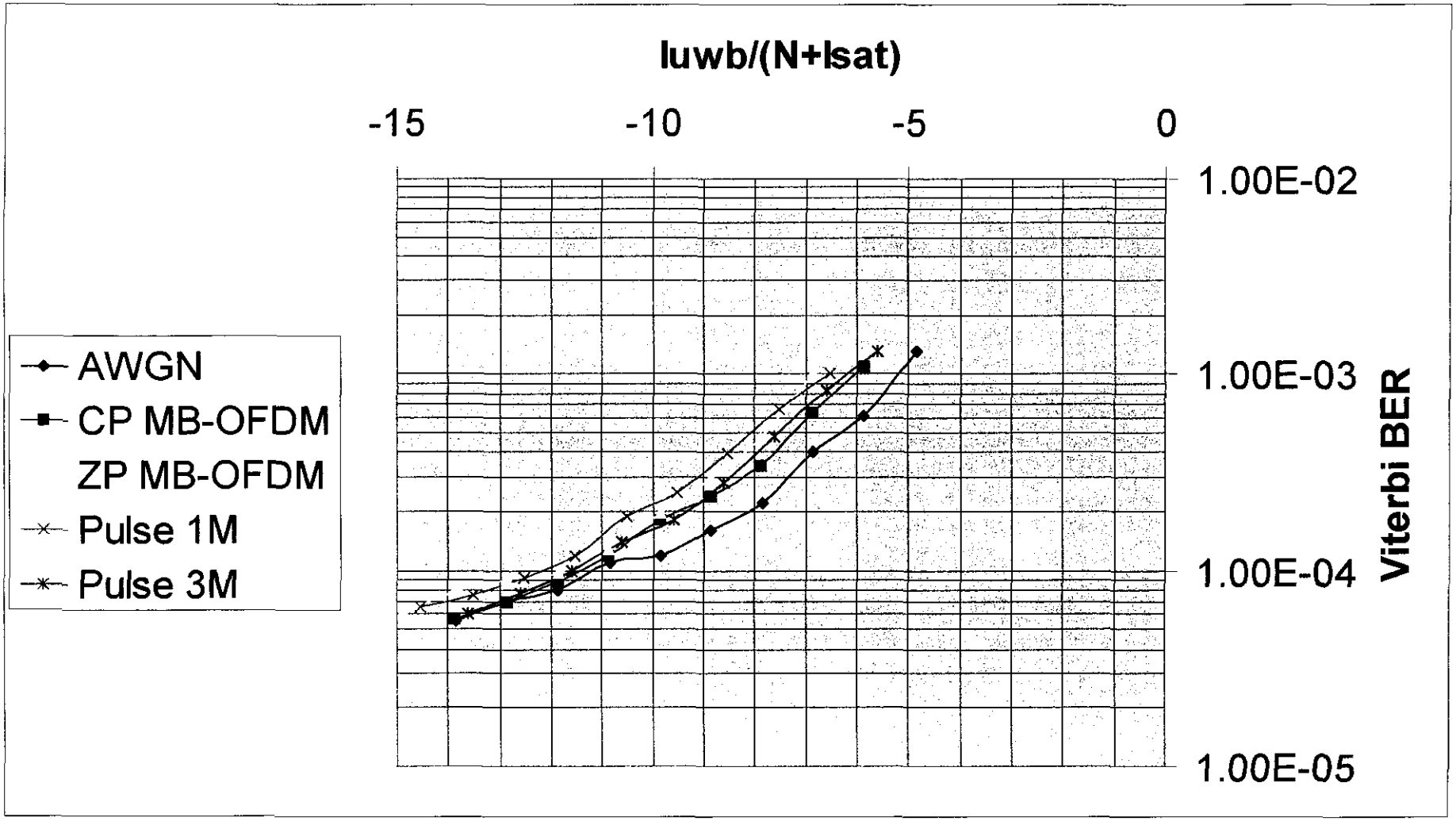
Wisair Conducted Measurements

- Measurements were taken with a digital C-Band victim receiver in a carefully calibrated laboratory environment
- Performed testing for 2.5 Msps and 20 Msps with convolutional and RS encoders
- Measurement results match simulation results when considering measurement accuracy and implementation degradation
  - Less than 1.5 dB difference between MB-OFDM and AWGN for 20 Msps receivers under realistic operating conditions similar to simulation and analysis results
  - No difference between MB-OFDM and AWGN for 2.5 Msps receivers

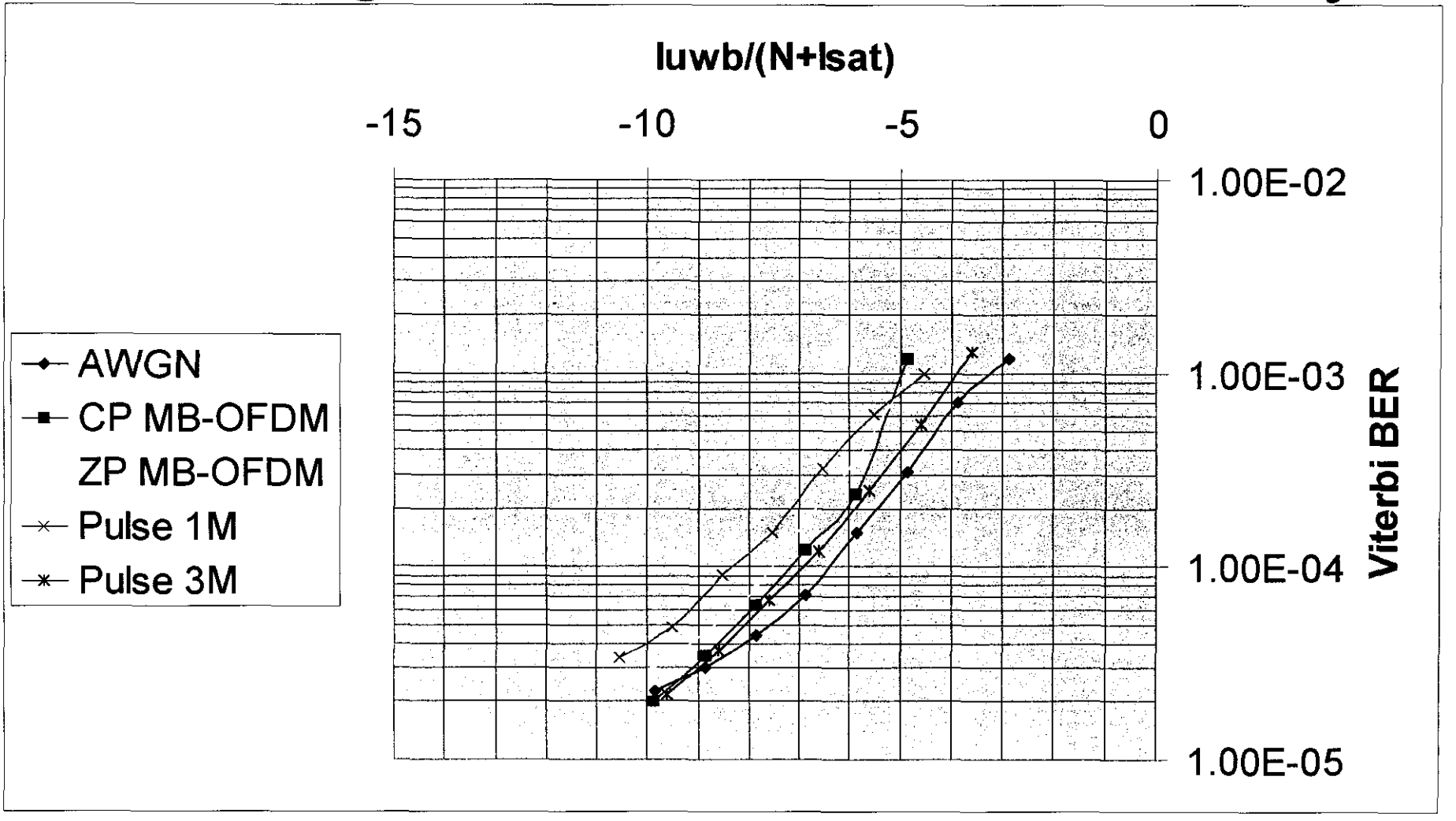
Measurement Test Setup



Measurement Results (1)
FSS signal ~0.5 dB above Sensitivity



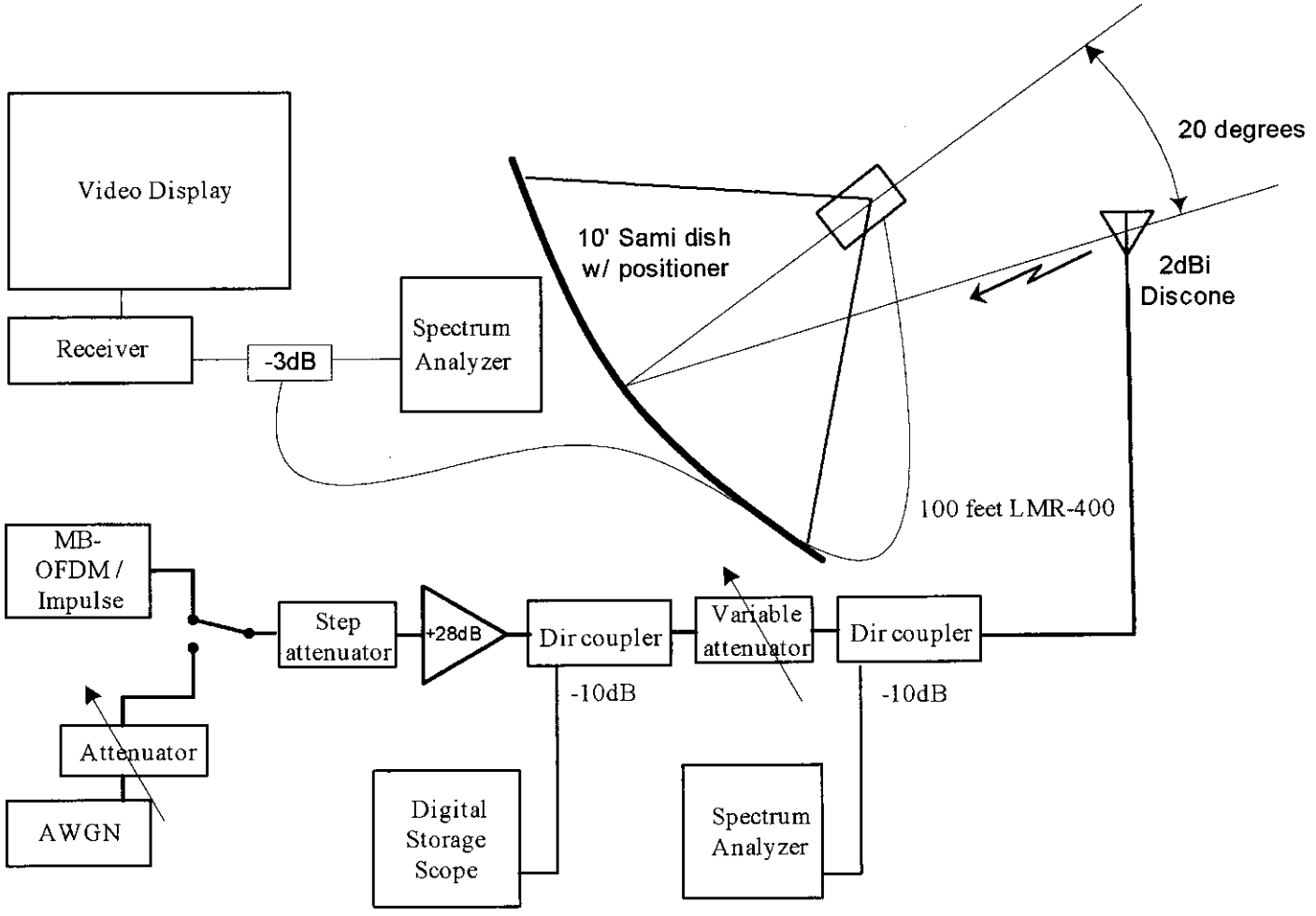
Measurement Results (2)
FSS signal ~1 dB above Sensitivity



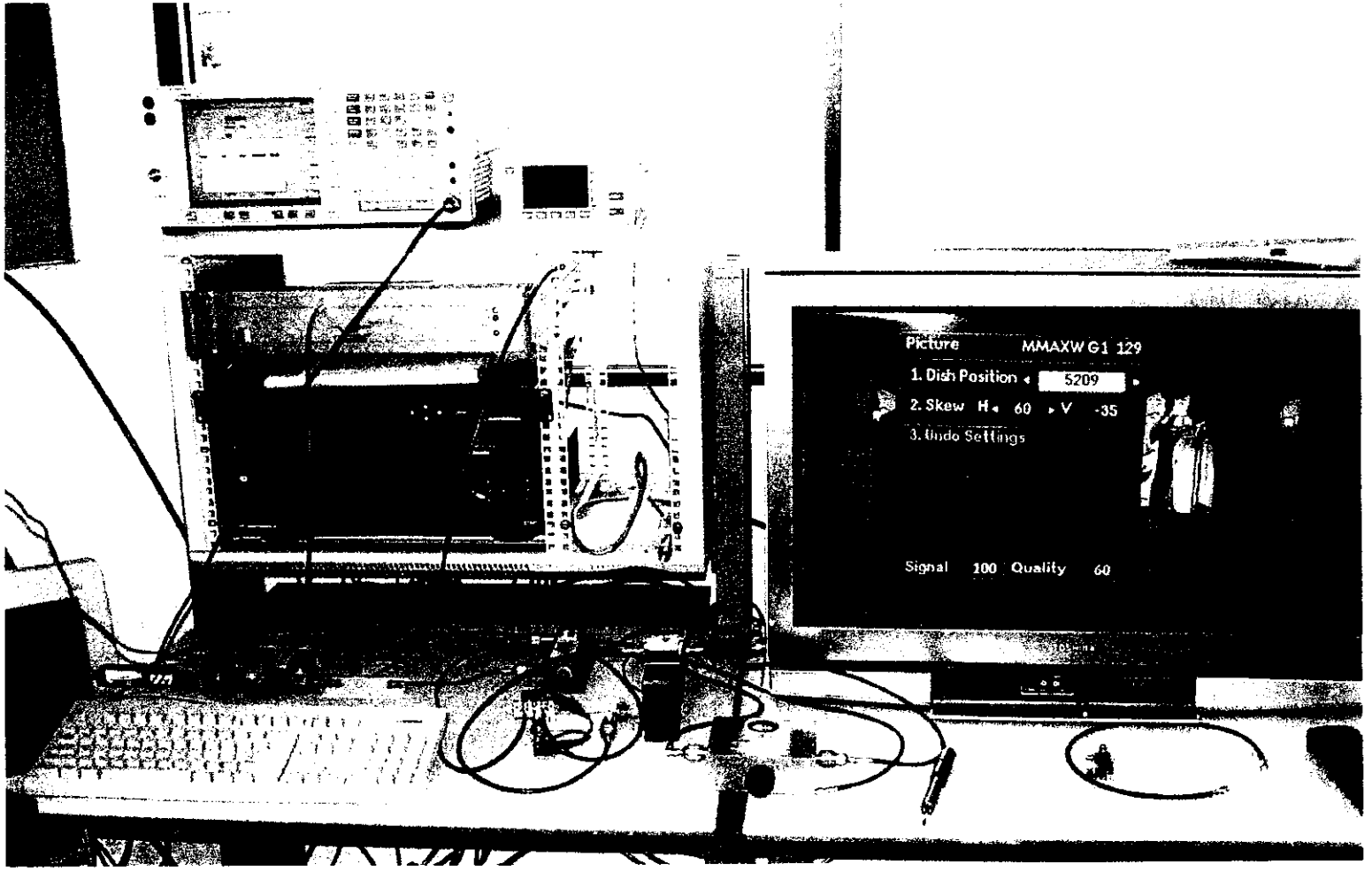
Interference Measurements at TDK RF test range

- Interference measurements conducted at TDK RF test facility in Austin, TX Dec 8-18, 2003
- Victim receiver is C-Band television broadcast
  - fc=4.16GHz
  - Digicipher II stream (QPSK, 7/8 FEC, 29.27Ms/s)
- Dish size selected as typical for the Austin area
- Interference measurements conducted over entire receiver operating margin:
  - 0.5 dB above sensitivity
  - 1.0 dB above sensitivity
  - 2.5 dB above sensitivity (maximum)
- Detailed test report in a later document.

INTERFERENCE TEST BLOCK DIAGRAM



Test equipment setup



Interference threshold Measurements dB relative to AWGN

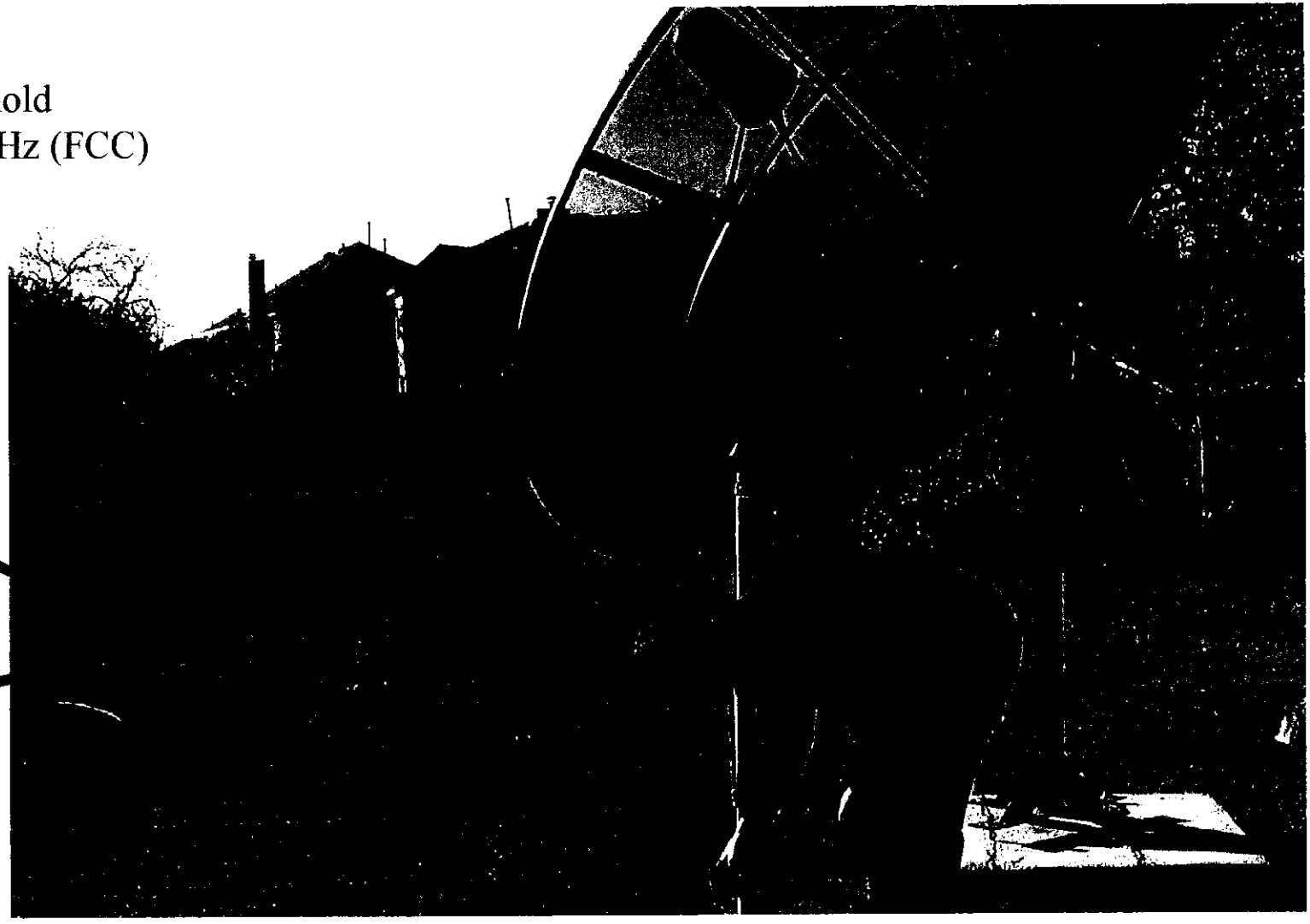
Emission	0.5dB Above Sensitivity	1dB Above Sensitivity	2.5dB Above Sensitivity
AWGN (DSSS)	0.0dB	0.0dB	0.0dB
MB-OFDM	-1.1dB	-1.2dB	-1.6dB
Impulse 3 MHz PRF	-1.9dB	-3.8dB	-4.0dB

Separation Distance Test

Interference Threshold
at -41.3dBm per MHz (FCC)

Red flags mark
AWGN

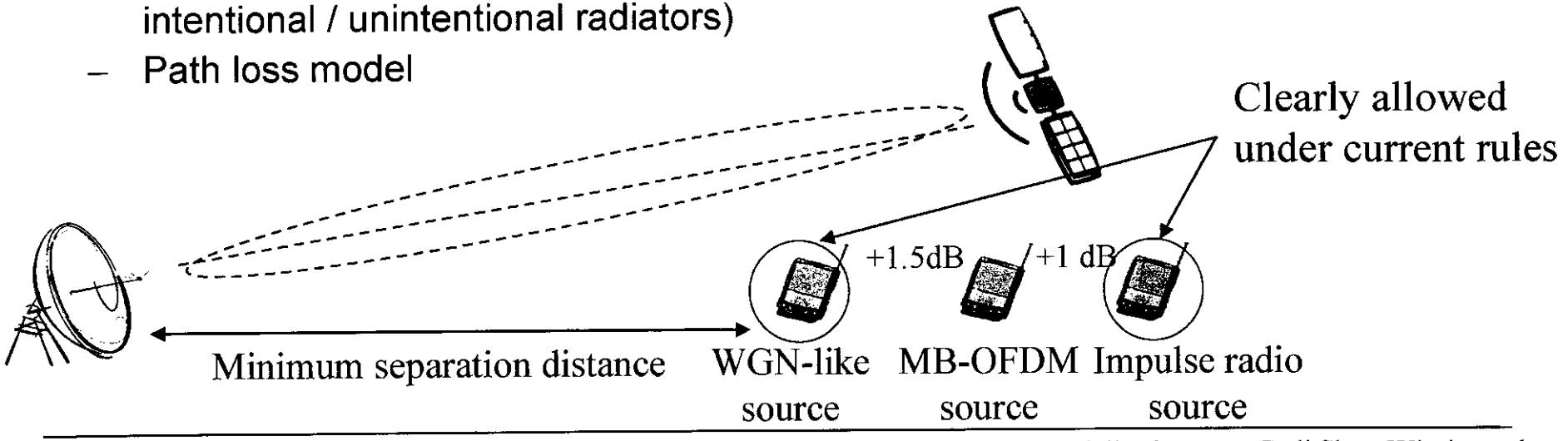
Green flags mark
MB-OFDM



Summary of Results and Conclusions

Summary of FSS Interference Studies

- Analysis, simulations, and measurements for wideband FSS systems all come up with the same results
  - MB-OFDM causes ~ 1 dB less interference than 1 MHz PRF impulse radio (with nsec pulse duration)
  - MB-OFMD is < 1.5 dB more interference than WGN
  - Impact on FSS link margin is on order of *tenths of a dB (~0.1 dB)* difference under realistic scenarios
  - Results do not show 'substantial' interference potential claimed by Motorola
- Relative differences are very small when other parameter variations are considered:
  - Antenna response (elevation and azimuth gain)
  - Operating signal level relative to thermal noise floor
  - Presence of other sources of interference (intra-system interference, other intentional / unintentional radiators)
  - Path loss model



Conclusions

- MBOA has followed FCC's directions to perform technical analyses to ensure that the UWB standard does not cause levels of interference beyond that already allowed by the rules
  - These results have already been presented to the FCC
  - MBOA can reproduce test setup if companies are interested in further testing and/or validation of results
- Simulation, analysis and measurements of FSS systems were performed by several companies in the MBOA
  - Measurement results have been validated by 2 independent tests
  - Results have shown levels of interference similar to what is already allowed by the rules
- MBOA will continue to work with the FCC to expedite resolution of this issue

What does this mean for the IEEE voters?

- Simulations, analysis, and measurements all show
  - MB-OFDM waveform causes no greater interference than 1 MHz impulse radios allowed under the rules
  - Worst-case difference (for wideband receivers) between MB-OFDM and WGN is ~1.5 dB for a fixed FSS performance level
  - Impact on FSS link margin is on order of *tenths of a dB (~0.1 dB)* difference under realistic scenarios
  - All UWB devices need to be very close to a FSS antenna before interference is seen
- Voters need to consider these results when casting their vote.

IP Position of MB-OFDM Proposal

Companies with significant IP in the proposal have already issued statements for royalty free licensing

- Alereon
- INTEL
- Staccato Communications
- Texas Instruments
- Wisair

- All author companies will conform to the IEEE patent policy and issue a letter of assurance.
  - Most have already signed a RAND statement

Time to Market

MB-OFDM Meets TTM Needs

Time to Market

- "No Voters" expressed concerns about TTM
- Claims that XSI solution would be much earlier to market
- Concerns expressed that MB-OFDM Time To Market would be unacceptable to users